UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY
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ANN ARBOR, MICHIGAN 48105-2498

OFFICE OF
AIR AND RADIATION

March 11, 2004 CCD-04-06 (LDV/LDT)

Dear Manufacturer:

Subject: Updated Analytically Derived Fuel Economy (ADFE) Policy for 2005 MY and Later

Attached to this letter are revised guidelines applicable to the use of analytically derived fuel economy (ADFE). Use of ADFE has been available from the beginning of the fuel economy program. The provisions of 40 CFR 600.006-89(e) allow EPA to accept analytical expressions to generate fuel economy data. In the early 1980's, a fuel economy sensitivity equation was developed and was used in conjunction with EPA Advisory Circular 83A to implement the ADFE program. On May 12, 1995, EPA published guidance letter number CD-95-08 which substantially expanded the use of ADFE and provided new sensitivity equations which included a statistical confidence factor for the first time. On April 24, 2000, EPA published guidance letter CD-00-04 which provided an interim method to use the existing ADFE equations for testing conducted on a single roll dynamometer using the three-term road force equation. The guidance in CD-00-04 was set to expire after the 2004 model year, by which time EPA anticipated that a new equation would be developed using only single roll dynamometer data. This letter provides that updated equation.

The updates presented in this letter are based in large part on discussions with and data submitted by the Alliance of Automobile Manufacturers (Alliance). The changes include updated ADFE equation coefficients, to allow data from all drivetrain types (2WD, 4WD and AWD) to be pooled together under specific conditions, to allow manufacturers to submit their ADFE documentation upon EPA request, and to expand the maximum fuel economy allowed from 10 percent to 20 percent from the baseline test.

All other previous provisions for ADFE usage will continue to apply. The full details about the sensitivity coefficients, baseline test selection, restrictions, and required documentation are contained in the Enclosure 1.

Enclosure 2 contains the details of the regression analysis used to calculate the ADFE equation coefficients which are contained in this letter. This enclosure was provided by the Alliance.

The analytical equation and procedures enclosed with this letter are effective immediately for model year 2005 and later vehicles, and replace the guidance on ADFE presented in EPA guidance letters numbers CD-95-08 and CCD-00-04. A manufacturer may optionally use these guidelines and equations for model years prior to 2005. EPA retains the right to order actual

confirmatory testing if necessary to assure the integrity of the fuel economy program or if there is a concern about emissions compliance.

EPA believes these updated ADFE guidelines represent a reasonable balance between the need for accurate fuel economy data and the need to contain the cost of testing for both industry and EPA.

Please contact Mr. Eldert Bontekoe at (734) 214 4442 or your Certification Team Representative if you any questions related to the ADFE process.

Sincerely,

Merrylin Zaw-Mon, Director
Certification and Compliance Division
Office of Transportation and Air Quality

Enclosures (2)

Enclosure 1 to CCD-04-06

Updated Analytically Derived Fuel Economy (ADFE) Guidelines

1. Without prior EPA approval, manufacturers may select the baseline test to be used for an ADFE, providing the following guidelines are followed:

   a. Vehicles considered for selection for the baseline test must pass all applicable emission standards in the model year associated with the ADFE.

   b. All official tests (which pass all applicable standards) of the same or equivalent basic engine, transmission class, engine code, transmission code, engine horsepower, dynamometer drive wheels, and compression ratio as the ADFE subconfiguration must be included in the pool of tests which will be considered for baseline selection.

   c. In order to minimize the mpg adjustment, the manufacturer may supplement the pool with tests associated with worse case engine or transmission codes and carryover or carry-across engine families. In these cases, all the data which qualifies for inclusion using the elected worse-case substitution (or carryover or carry-across) must be included in the pool as supplemental data (i.e., individual test vehicles may not be selected for inclusion). Once the manufacturer decides to supplement the pool in this manner, the supplemental data must be included in all subsequent pools, where applicable.

   d. To limit the effect of an "above average" test, tests previously used during the subject model year as baseline tests in five other ADFE subconfigurations must be eliminated from the pool.

   e. All remaining tested subconfigurations in the pool must be evaluated against the target ADFE subconfiguration by using the new three-parameter composite mpg coefficient including the 95% confidence limits.

   f. The tested subconfiguration with the smallest net combined fuel economy adjustment (i.e., smallest absolute value of (ADFE - test FE)) for combined fuel economy) will be selected as the baseline test for the target ADFE subconfiguration and used for both city and highway adjustments.

2. Any proposed baseline test not selected according to the provisions of paragraph 1 (above), must be reviewed and approved by EPA on a case-by-case basis.

3. The ADFE will be calculated using the three-parameter 95% confidence limits as listed on the following table. The result shall be rounded to a tenth of an mpg. The upward

adjustment of ADFE from the baseline shall be limited to 20% over the baseline fuel economy (i.e., baseline fuel economy X 1.2). The downward adjust is not limited.

ADFE Coefficients

Parameter	City Fuel Economy		Highway Fuel Economy	
	parameter increases	parameter decreases	parameter increases	parameter decreases
ETW	-0.532	-0.449	-0.308	-0.239
N/V	-0.173	-0.117	-0.274	-0.228
TRLHP	-0.213	-0.149	-0.460	-0.407

4. Manufacturers may not submit an ADFE if an actual test has been run on the target subconfiguration during the certification process or on a development vehicle which is eligible be declared as a fuel economy data vehicle.

5. To maintain the integrity of the fuel economy program, manufacturers may not use ADFE under the following circumstances:

   a. For Passenger Automobile labels - manufacturers may not use any ADFE with a combined fuel economy of less than 1.0 mpg above the Gas Guzzler Tax $0 threshold (currently this limit is 23.5 mpg - see 40 CFR 600.513-91).

   b. For Passenger Automobiles and Light Truck labels - manufacturers may not use any ADFE with a combined fuel economy greater than or equal to the leader in the applicable Vehicle Classification Class based on the previous model year's unadjusted general label values rounded to a whole mpg. If manufacturers are unaware of these values they must contact their Certification Team Representative before using ADFE.

6. To limit the impact of ADFE on CAFÉ, no more than 20 percent of the subconfigurations tested in a manufacturer's final CAFÉ may be represented by ADFE. For example, if the manufacturer has 100 subconfigurations which are tested (or represented through data substitutions and equivalencies), only 20 of the 100 may be based on ADFE calculations (or represented through data substitutions or equivalencies from ADFE generated data points).

7. The manufacturers must retain for five years (under the provisions of 40 CFR 600.005-81(a)(3)) the pool of tests, the vehicle description and tests chosen as the baseline and the basis for its selection, the target ADFE subconfiguration and the calculated city and highway adjusted fuel economy. EPA may request this information as part of an audit.

8. If EPA determines that it is necessary to assure the integrity of the fuel economy database or if EPA has concerns about compliance with emission standards, EPA retains the right to order a confirmatory test of the subconfiguration covered by the ADFE.

   If the manufacturer chooses, EPA will accept a temporary Fuel Economy Label based on the ADFE while a suitable data vehicle is being procured. However, if the confirmatory test value results in a lower rounded fuel economy value (city, highway, or combined) for any model type the label must be updated. The updated label value shall be used on all vehicles produced more than 15 days following its submission.

9. EPA is presenting this option as a manufacturer self-approval process. EPA will not be responding to routine submissions of ADFE data indicating our acceptance of the calculation or waiver of confirmatory testing.

If EPA later discovers that the procedures for self-approval were not followed, EPA may rescind the use of ADFE data and require actual test data be generated and require recalculation of labels and CAFE values.

Enclosure 2 to CCD-04-06 -- ADFE Equation Development

General Note: The development of the ADFE coefficients mirrors the process used to develop the 1996 ADFE equation and coefficients.

Dataset

Single roll tests from the 2000-2004 test car lists through September 2003 were included in the original database. Only official data is contained in the EPA test car lists.

Dataset only includes tests on gasoline test fuel (6272 tests)
ADFE were deleted (570)
Duplicate tests were deleted (1724)
HEV, AFV, 91 Octane tests were deleted (252)
Suspect tests were deleted (147)

- Suspected high or low TRLHP
- Frontal area DPA
- Three known outliers

Unique vehicle tests were deleted (162)

- 12 cylinder engines
- Prowler
- Rotary engine
- Engine horsepower greater then 380

Suspect dual rolls tests (127)
Total tests removed from the dataset: **2624**

Total tests in the dataset: 3642, approximately half city and half highway

Test parameters on several tests were corrected based on manufacturer information.
The drive data was corrected and 4WD and AWD information was converted to either FWD or RWD, based on how the vehicle was tested.

Data Analysis

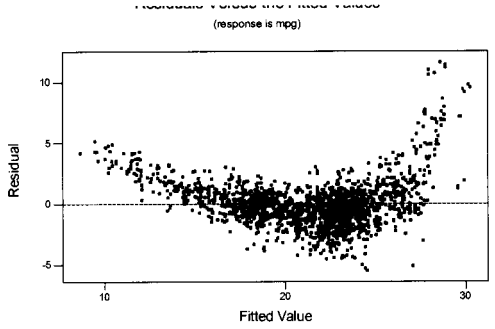
1. An initial regression was performed which considered most of the vehicle parameters in the test car list and a number of technologies including valves per cylinder, VVT, turbo or supercharging. The following parameters were selected based on this analysis: ETW, TRLHP, N/V, CID, HP, drive and car and truck indicators.
2. Regressions were run to verify that the ln function gave a better correlation than an analysis based on the straight values of the parameters (the ln function was used in the development of the original coefficients)
3. Stepwise regression was used to verify the significant factors.
4. Multiple regressions were run to identify whether separate equations should be established based on the significant factors and that use of a city TRLHP at 20 mph would not improve correlation of the data.

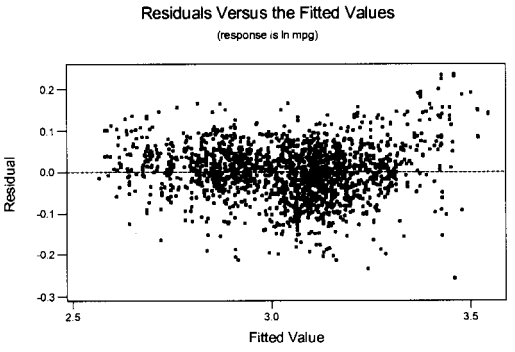
Results

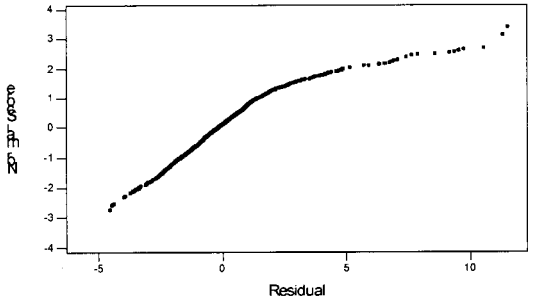
- Using the ln function resulted in a better correlation, and therefore was preferred over the use of the straight values.
- There was no improvement in the correlation if separate equations were developed for car and truck, or front or rear wheel drive or by using the TRLHP at 20 mph for the city tests over a TRLHP at 50 mph.
- Car and truck, drive, cid, hp, VVTi were all considered significant in the development of the coefficients and therefore remained in the final analysis.

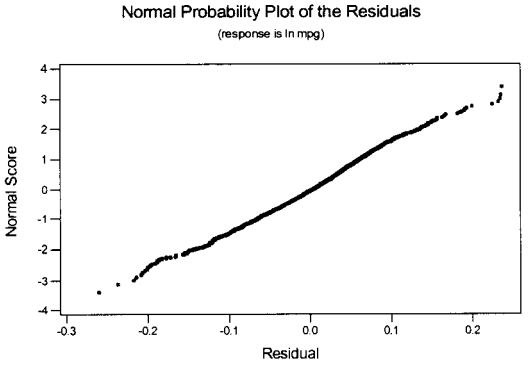
Proposed coefficients for car and truck

Parameter	City Fuel Economy		Highway Fuel Economy	
	parameter increases	parameter decreases	parameter increases	parameter decreases
ETW	-.532	-.449	-.308	-.239
N/V	-.173	-.117	-.274	-.228
TRLHP	-.213	-.149	-.460	-.407









Test of appropriate analysis method

straight values	ln of values

Regression Analysis: mpg versus etw, c/t, drive, cid, hp/cid, n/v, trlhp (All data)

The regression equation is

mpg = 74.6 - 0.00216 etw - 1.14 c/t + 0.155 drive - 0.0449 cid - 2.87 hp/cid

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          - 0.227 n/v - 0.803 trlhp

Predictor        Coef     SE Coef          T        P
Constant      74.5554      0.9617      77.52    0.000
etw        -0.0021638   0.0001989     -10.88    0.000
c/t           -1.1414      0.2334      -4.89    0.000
drive         0.15463     0.05704       2.71    0.007
cid         -0.044870    0.002050     -21.89    0.000
hp/cid        -2.8660      0.2995      -9.57    0.000
n/v           -0.22660     0.01496     -15.15    0.000
trlhp         -0.80292     0.04296     -18.69    0.000

S = 2.442       R-Sq = 85.4%     R-Sq(adj) = 85.4%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         7     63066.4      9009.5   1510.52    0.000
Residual Error  1806     10771.8         6.0
Total           1813     73838.2
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The correlation using the ln method is better at 92.6% and the normal probability plots and residuals vs. fits indicate that the ln function better represents the population.

City Data

Stepwise Regression: ln mpg versus c/t, drive, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15
Response is ln mpg on 8 predictors, with N = 1833

Step	1	2	3	4	5	6
Constant	10.462	10.137	9.923	9.625	9.450	9.505
ln n/v	0.028	-0.159	-0.168	-0.163	-0.145	-0.145
T-Value	1.73	-10.31	-11.37	-11.45	-10.27	-10.27
P-Value	0.085	0.000	0.000	0.000	0.000	0.000
ln etw	-0.863	-0.582	-0.497	-0.460	-0.486	-0.490
T-Value	-38.07	-26.73	-22.78	-21.68	-23.05	-23.21
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
ln trlhp	-0.142	-0.113	-0.170	-0.177	-0.155	-0.181
T-Value	-9.63	-9.03	-13.40	-14.39	-12.61	-11.24
P-Value	0.000	0.000	0.000	0.000	0.000	0.000
ln cid		-0.270	-0.200	-0.196	-0.158	-0.160
T-Value		-27.05	-18.29	-18.66	-13.97	-14.09
P-Value		0.000	0.000	0.000	0.000	0.000
ln hp			-0.1277	-0.1327	-0.1299	-0.1226
T-Value			-13.22	-14.25	-14.19	-12.76
P-Value			0.000	0.000	0.000	0.000
VVTI				0.0818	0.0818	0.0809
T-Value				11.92	12.13	11.99
P-Value				0.000	0.000	0.000
drive					0.0333	0.0336
T-Value					8.27	8.33
P-Value					0.000	0.000
c/t						0.0150
T-Value						2.48
P-Value						0.013
S	0.0830	0.0701	0.0670	0.0646	0.0634	0.0633
R-Sq	81.66	86.90	88.05	88.91	89.31	89.35
R-Sq(adj)	81.63	86.87	88.01	88.87	89.27	89.30
C-p	1314.7	419.1	225.4	79.7	13.1	9.0

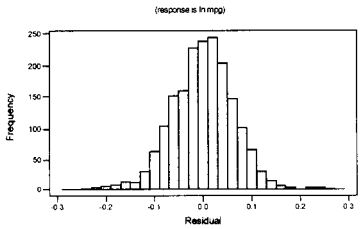
Conclusion - all significant except c/t, correlation improves with the addition of the indicators.

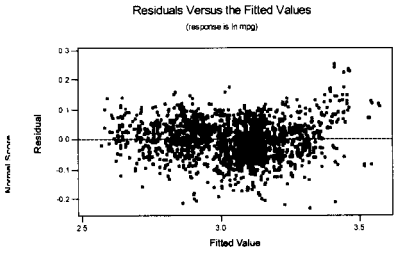
Regression Analysis: ln mpg versus ln etw, ln n/v, ... (all parameters)

The regression equation is
ln mpg = 9.51 - 0.490 ln etw - 0.181 ln trlhp - 0.145 ln n/v + 0.0150 c/t
+ 0.0336 drive - 0.160 ln cid - 0.123 ln hp + 0.0809 VVTI

Predictor	Coef	SE Coef	T	P
Constant	9.5054	0.1566	60.69	0.000
ln etw	-0.49040	0.02113	-23.21	0.000
ln trlhp	-0.18127	0.01613	-11.24	0.000
ln n/v	-0.14482	0.01411	-10.27	0.000
c/t	0.015014	0.006055	2.48	0.013
drive	0.033561	0.004027	8.33	0.000
ln cid	-0.15956	0.01132	-14.09	0.000
ln hp	-0.122576	0.009607	-12.76	0.000
VVTI	0.080855	0.006741	11.99	0.000

S = 0.06334 R-Sq = 89.3% R-Sq(adj) = 89.3%





Analysis of Variance

Source	DF	SS	MS	F	P
Regression	8	61.3597	7.6700	1911.91	0.000
Residual Error	1824	7.3173	0.0040		
Total	1832	68.6770			

Source	DF	Seq SS
ln etw	1	55.4431
ln trlhp	1	0.6180
ln n/v	1	0.0205
c/t	1	0.4107
drive	1	1.8484
ln cid	1	1.8583
ln hp	1	0.5837
VVTI	1	0.5771

Regression Statistics	
Multiple R	0.94522351
R Square	0.893447484
Adjusted R Square	0.892980148
Standard Error	0.063339575
Observations	1833

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	61.35930737	7.6699134	1911.79	0
Residual	1824	7.317708865	0.0040119		
Total	1832	68.67701623			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	9.507	0.157	60.672	0.000	9.199	9.814
c/t	0.015	0.006	2.468	0.014	0.003	0.027
drive	0.034	0.004	8.329	0.000	0.026	0.041
ln cid	-0.160	0.011	-14.097	0.000	-0.182	-0.137
ln hp	-0.123	0.010	-12.768	0.000	-0.141	-0.104
ln n/v	-0.145	0.014	-10.272	0.000	**-0.173**	**-0.117**
ln etw	-0.490	0.021	-23.206	0.000	**-0.532**	**-0.449**
ln trlhp	-0.181	0.016	-11.227	0.000	**-0.213**	**-0.149**
VVTI	0.081	0.007	11.998	0.000	0.068	0.094

Stepwise Regression: ln mpg versus c/t, drive, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15
Response is ln mpg on 8 predictors, with N = 1810

Step	1	2	3	4	5	6	7
Constant	5.153	7.434	9.423	9.235	9.082	8.999	8.949
ln n/v	0.100	-0.231	-0.272	-0.253	-0.249	-0.252	-0.252
T-Value	6.90	-17.79	-22.14	-20.97	-20.98	-21.36	-21.40
P-Value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ln trlhp	-0.7635	-0.5620	-0.4519	-0.4309	-0.4335	-0.4545	-0.4323
T-Value	-80.45	-67.68	-44.99	-43.30	-44.20	-43.80	-32.03
P-Value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ln cid		-0.3145	-0.2506	-0.2067	-0.2064	-0.1834	-0.1822
T-Value		-41.84	-31.66	-23.64	-23.98	-19.48	-19.35
P-Value		0.000	0.000	0.000	0.000	0.000	0.000
ln etw			-0.298	-0.325	-0.307	-0.276	-0.272
T-Value			-17.08	-18.96	-18.05	-15.54	-15.26
P-Value			0.000	0.000	0.000	0.000	0.000
drive				0.0363	0.0359	0.0351	0.0349
T-Value				10.56	10.59	10.44	10.40
P-Value				0.000	0.000	0.000	0.000
VVTI					0.0440	0.0456	0.0466
T-Value					7.54	7.87	8.05
P-Value					0.000	0.000	0.000
ln hp						-0.0438	-0.0500
T-Value						-5.77	-6.28
P-Value						0.000	0.000
c/t							-0.0129
T-Value							-2.56
P-Value							0.010
S	0.0840	0.0599	0.0556	0.0540	0.0531	0.0527	0.0526
R-Sq	82.14	90.93	92.19	92.65	92.87	93.00	93.03
R-Sq(adj)	82.12	90.92	92.17	92.63	92.85	92.97	92.99
C-p	2808.4	540.2	216.3	101.0	44.9	13.6	9.0

Conclusion, all parameters are significant, correlation improves with addition of parameters.

Regression Analysis: ln mpg versus ln etw, c/t, ...(all parameters)

The regression equation is

ln mpg = 8.95 - 0.272 ln etw - 0.0129 c/t + 0.0349 drive - 0.182 ln cid
- 0.252 ln n/v - 0.432 ln trlhp - 0.0500 ln hp + 0.0466 VVTI

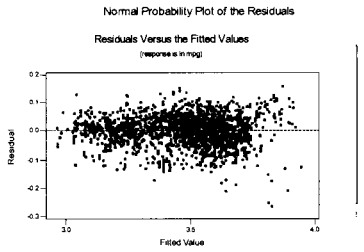
Predictor	Coef	SE Coef	T	P
Constant	8.9491	0.1321	67.76	0.000
ln etw	-0.27157	0.01780	-15.26	0.000
c/t	-0.012949	0.005053	-2.56	0.010
drive	0.034914	0.003358	10.40	0.000
ln cid	-0.182196	0.009417	-19.35	0.000
ln n/v	-0.25205	0.01178	-21.40	0.000
ln trlhp	-0.43230	0.01350	-32.03	0.000
ln hp	-0.050031	0.007963	-6.28	0.000
VVTI	0.046623	0.005792	8.05	0.000

S = 0.05259 R-Sq = 93.0% R-Sq(adj) = 93.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	8	66.4320	8.3040	3002.89	0.000
Residual Error	1801	4.9804	0.0028		
Total	1809	71.4124			

Source	DF	Seq SS
ln etw	1	54.6247
c/t	1	3.5881
drive	1	2.6664
ln cid	1	0.7294
ln n/v	1	1.7560
ln trlhp	1	2.7965
ln hp	1	0.0917
VVTI	1	0.1792



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.96460
R Square	0.93045
Adjusted R Square	0.93014
Standard Error	0.05247
Observations	1810

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	8	66.325	8.291	3011.906	0
Residual	1801	4.957	0.003		
Total	1809	71.282			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	8.948	0.132	68.002	0.000	8.690	9.206
c/t	-0.012	0.005	-2.442	0.015	-0.022	-0.002
drive	0.035	0.003	10.454	0.000	0.028	0.042
ln cid	-0.180	0.009	-19.151	0.000	-0.198	-0.161
ln etw	-0.274	0.018	-15.427	0.000	-0.308	-0.239
ln n/v	-0.251	0.012	-21.369	0.000	-0.274	-0.228
ln trlhp	-0.434	0.013	-32.135	0.000	-0.460	-0.407
ln hp	-0.049	0.008	-6.186	0.000	-0.065	-0.034
VVTI	0.047	0.006	8.181	0.000	0.036	0.059